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The Giant Gippsland Earthworm, *Megascolides australis*, population at Loch Hill, South Gippsland : distribution and preliminary biological and soil studies

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Abstract

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A preliminary study of the distribution, soils and biology of the Giant Gippsland Earthworm at Loch Hill was conducted between September and November 2001. This population occurs in the vicinity of proposed roadworks for the South Gippsland Highway between Loch and Bena.

The earthworm population at Loch Hill was found to have a relatively restricted distribution, confined to an area of approximately 2500m^2, extending south-east of the tree fern, across the face of the hill to just past the seepage channel. The population extends downslope to just above the tributary of Allsop Creek but is absent from the valley floor. Soil investigations reveal that this area corresponds to a section of the hill with very pronounced terracettes, indicating that the land surface is wetter than the surrounding area.

Worms appeared to be widespread within their area of distribution. Six quadrats were examined for worm density from which a total of 23 worms were recorded. Worm density within this area was very high ranging from 4.1 to 17.9 worms per m^3 with an average of 8.5 worms per m^3 calculated. This indicates a very high density of worms at Loch Hill.

A range of age classes were found with adult, subadult and juvenile worms recorded. The largest worm found weighed 250g. No breeding adults were found despite sampling occurring within the known breeding season.

If road works proceed in the area occupied by the Giant Gippsland Earthworm population at Loch Hill, the entire earthworm habitat at the site would be lost. The impacts of road works at the site on the species are discussed and include directly killing individuals and injury of earthworms during soil excavation, compacting the soil and altering the soil habitat in particular drainage and moisture regimes at the site.

The only mitigation measure available is to attempt to 'rescue' the existing population before and during roadworks and endeavour to protect or restore any earthworm habitat near by that may escape the direct impacts of the roadworks. Research opportunities resulting from this situation and their benefits to the long term survival and conservation of this species are discussed.

1. DISTRIBUTION AND PRELIMINARY BIOLOGICAL STUDIES AT LOCH HILL

Background

Museum Victoria was contracted by Vic Roads in October 2000 to investigate the potential impact on the Giant Gippsland Earthworm, *Megascolides australis*, of road and bridge construction works on the South Gippsland Highway around Loch and Bena (Van Praagh and Hinkley 2000a, b, c, 2001). During these surveys, a population of *M. australis* was located at Loch Hill (Van Praagh and Hinkley 2000b). Further surveys were conducted at this site in July 2001 after roadworks associated with bore testing and soil excavation occurred within the vicinity of the earthworm population (Van Praagh and Hinkley 2001). This work revealed that the area supported a large population of the species, which was more widespread at the site than previously thought. Assessment of the site after the disturbance indicated that the works resulted in the destruction of some earthworm habitat and individual earthworms, though exact numbers were difficult to estimate.

Museum Victoria was further contracted (August 2001) to provide advice on what mitigation measures (if any) may be effective for protection of the remaining population of *M. australis* at Loch Hill. The objectives of the project are:

- Identification of the specific area inhabited by the earthworm colony by determining the AMG co-ordinates for boundary corners (using GPS).
- Estimation of the depth occupied by worms.
- Evaluation of the density per m^3 of worms in the area.
- Assessment of the potential impacts that the roadworks could have on the colony.
- Identification of measures that could be implemented to prevent or minimise the potential impacts on *M. australis*.
- Assessment of soils where *M. australis* occurs.

Methods

Distribution. The distribution of *M. australis* at Loch Hill was obtained by surveying the site in and around the vicinity of the known locations. This involved digging and looking for signs of the worms' presence. Quadrats of approximately 50 cm x 50 cm were dug to examine the soil for Giant Gippsland Earthworm burrows. Burrows are easily identified and, if wet, represent burrows that are actively being utilised by the

worms. If the ground is wet, presence of the worms can also be established by banging the ground with a spade and listening for gurgles, the sound that is made when the worms retreat down their burrows.

Sampling began just east of the lone tree fern and continued east across the hillside until no more worms were located. Sampling extended downslope to the creek at the bottom of Loch Hill. Areas above the road cutting were also surveyed.

Density and population structure. Information regarding earthworm density and population structure was obtained by extensive digging of large quadrats to obtain individual specimens. Quadrats were located in areas where active earthworms were detected from the distribution survey such as those with wet burrows or where gurgles were heard. Once the soil was exposed, the site was searched for wet burrows. Wet burrows were then followed carefully until the worm was found and part of its body exposed. Once exposed, the entire worm was slowly dug out of the burrow, using a trowel. Individual worms were then measured and weighed and their reproductive status recorded. It is difficult to obtain an accurate estimate of worm size due to the worms' ability to expand and contract. A contracted worm can more than double its length when relaxed. Weight possibly gives a better comparative estimate of size, although this may vary according to amounts of soil consumed and that voided during capture. Depth of the worms was also recorded by measuring the depth in the soil when the worm was first observed. Worm density was estimated by calculating the number of worms located in a given area of soil dug.

Worms were classified into juveniles, subadult and adults based on the number and position of clitella banding (Van Praagh 1994). These small, light coloured bands occur on the ventral surface of the worm between segments xvii and xix. Juvenile worms have no external banding, subadults one or two and adults have three bands on segments xvii, xviii and xix. This information could only be obtained from worms that were fully dug up, or at least had their anterior segments exposed far enough so the clitella banding could be examined.

Unfortunately, even when great care is taken, individual worms can be killed or damaged through the excavation process. As the worms are very fragile, even bruising can result in death. Any worms injured or killed were fixed in formalin and preserved in 70% alcohol and retained in Museum Victoria collections for further research. Worms were relaxed in a mixture of 10% Magnesium sulphate and Magnesium chloride added to water, fixed in 10% formalin and stored in 70% alcohol. All uninjured worms were released at site of capture.

Not all worms sighted could be dug up. If worms were found very deep in the soil or where a large number of worms were found together, only the number and depth of the worms found was recorded as the risk of injury to other worms was considered to outweigh the successful capture and release of a worm.

Worm density is expressed per m^3 of soil. To take into account the hillslope when digging a quadrat, the average of the highest and lowest depth of the quadrat dug is used for the calculation. The estimation of the number of worms at Loch can also be given per m^2, assuming that most worms are in the top 1m of soil.

Mean densities were converted to logarithms to calculate the 95% confidence limits. Log transformations are used on small sample sizes where the sample is not randomly distributed over an area (Elliot 1977) as is the case with the Giant Gippsland Earthworm at Loch Hill.

Soil. A soil scientist, Ian Sargeant, an expert in soils of the South Gippsland region, was engaged to provide advice on soils at the study site where the worms occur at Loch Hill.

The distribution of the Giant Gippsland Earthworm at the study site is recorded on a map and the AMG/Lat Long coordinates provided.

Field trips were carried out on 12 September, 10 and 17 October, 13 and 28 November 2001.

Results

Distribution of* M. australis *at Loch Hill. The location and habitat characteristics of worm sites are given in table 1. Worms were located about 30 m SE of tree fern (site 1) (38° 22' 741 145° 43' 591) and continued down to just above the creek bank at the bottom of Loch Hill (38° 22' 742 145° 43' 545) (Plate 1a & 1b) Their distribution followed a band eastward across the hill to sampling point 14, close to the obvious drainage channel running downslope (38° 22' 742 145° 43' 563). This channel appeared to be fed by an underground spring evident in the cut face above the road (Plate 2). This coincides with the observed distribution of burrows in the cutting above the roadside, which appeared to diminish on the east side of the turn circle (38° 22'714 145° 43'591) (see Plate 2). Burrows appeared to be absent from the creek bank itself, although they were found close by into the hillslope (eg site 11). They were also absent from the area above the road cutting. Therefore the worms were confined to a fairly specific area of the hill. The area occupied by worms was approximately 2500 m^2. Within this area, worms were patchy but appeared to be quite dense in parts. Live worms were observed during this survey and gurgles were heard.

Biology and Density. Six quadrats were dug at Loch Hill to examine the density of earthworms and estimate their depth in the soil (Table 2). Three of these sites (site 1, 2 and 3) occurred just below the road cutting which was covered in fallen soil (Plate 3) and the remaining study sites occurred in undisturbed pasture toward the bottom of Loch Hill, about 10 m above the creek bank (site 4, 5 and 6) (Plate 4).

A large area of pasture below the road cutting was covered by soil from the excavation above. The pre-existing pasture was evident approximately 20-30 cm below the new soil line. Worms were located in this area and burrows were evident above the old pasture line, indicating that they had successfully burrowed into the new soil. A total of 9 worms were found from these three sites (see table 2). This included 4 juveniles, 1 subadult, 1 adult and 3 unknowns (worms not completely dug out).

A total of 14 worms were recorded from the three sites located toward the bottom of Loch Hill. These sites had a high density of burrows and worms (Plate 5 and 6). In particular, site 6 where such a large number of worms were encountered while digging, that it was very difficult to pursue many of the worms without damaging others. At one point, 5 worms were exposed at one time (Plate 7a and 7b).

At this site, one small juvenile worm was recorded which appeared to be fairly recently hatched. Two empty egg

cocoons were found, one of which appeared to be quite a recent hatchling and therefore may have been the one from which the juvenile worm had emerged. No unhatched egg cocoons were located during sampling. No breeding adults were found (ie adults with swollen clitella). Worms were found at a mean depth of 39.3 ± 16.6 cm.

Worms ranged in size from 25 cm to around 80 cm with weights ranging from 18 g for a newly hatched juvenile up to 250 g for an adult.

Overall Density. The number of worms found ranged from 1 to 9 with the mean density per m^3 ranging from 4.1 to 17.9. The high figure of 17.9 arises due to the small volume of soil dug to record the single individual found. The mean number of worms at the site is 8.5 m^{-2} with a 95% CL = 5 -14.5 m^{-2}. The area estimated to be occupied by worms at Loch Hill is 50 x 50 m (=2500m^2). Using the average density of worms (8.5), the total number of worms at Loch Hill is estimated to be 21,250 with 95% C. L limits of 12,500 –36,250 worms.

Plate 1a. Distribution of the Giant Gippsland Earthworm at Loch Hill

Plate 1b. Distribution of the Giant Gippsland Earthworm at Loch Hill

Plate 2. Distribution of Giant Gippsland Earthworms and seepage point at Loch Hill.

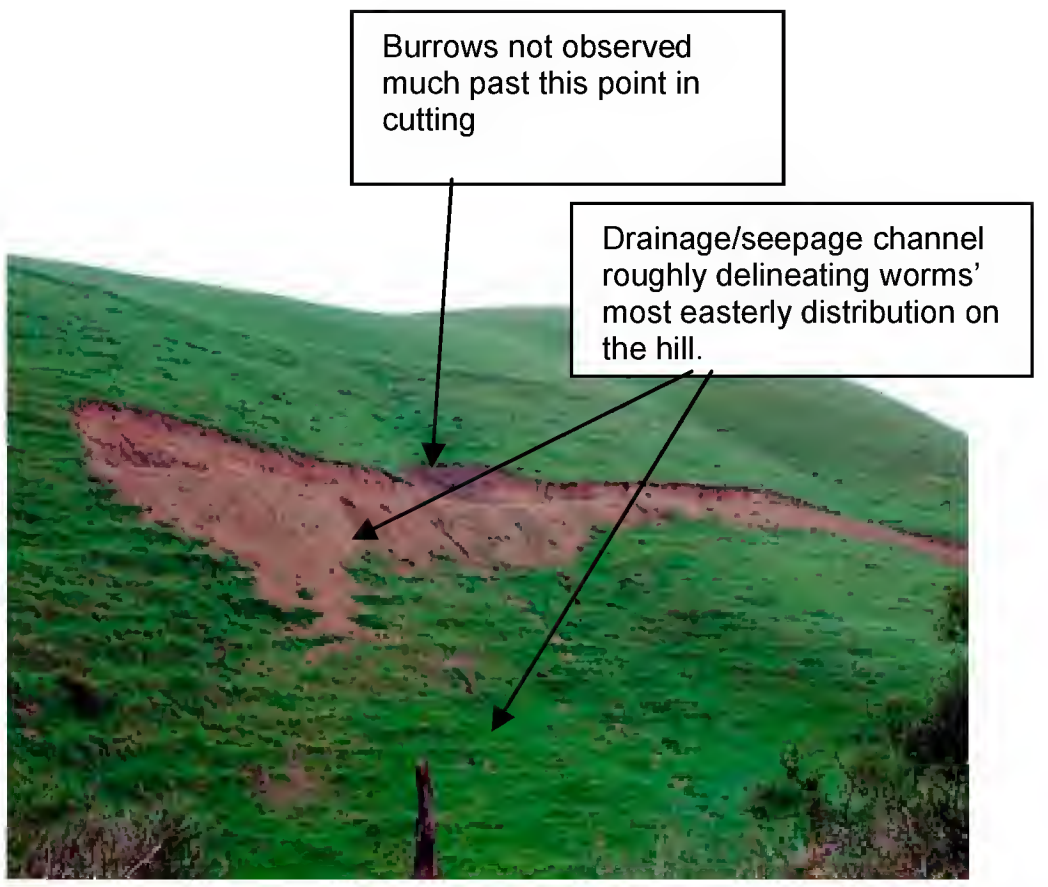
Burrows not observed much past this point in cutting
Drainage/seepage channel roughly delineating worms' most easterly distribution on the hill.

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Table 1. Distribution of Giant Gippsland Earthworm at Loch Hill

Distribution Point	Lat Long		Worm burrow density
1.	38º 22' 741" 145º 43' 548"	About 30m South of tree fern	Worm burrows and fresh cast
2.		2.5 m south of site 2.	
3.	38º 22' 732" 145º 43' 550"	1.5 m downslope from Site 2	High density of burrows
4.	38º 22' 742" 145º 43' 544"		Burrows and young GGE worm at 15 cm depth
5.	38º 22' 740" 145º 43' 540"		A few burrows (low density)
6.	38º 22' 729" 145º 43' 540"		A few burrows
7.	38º 22' 742" 145º 43' 540"	About 2m from creek bank at bottom of hillslope/steep bank.	Gurgle, wet burrow and a juvenile GGE
8.	38º 22' 739" 145º 43' 548"	About 10 m from creek in steep part of hillslope above bend in the stream.	Medium density burrows.
9.	38º 22' 737" 145º 43' 554"		1 adult worm at 10cm depth. High density of burrows
10.		Just below site 9.	High density of burrows
11.	38º 22' 740" 145º 43' 551"	Very steep section of hill about 4 m above creek. About 4 m below site 9.	Gurgle, very high density of burrows. Adult worm
12.	38º 22' 737" 145º 43' 558"	Just under level of soil excavation spill (from west).	Very high density of burrows. Close to surface. Wet burrows and gurgles.
13.	38º 22' 737" 145º 43' 560"	Middle of hillslope almost level with tree fern	Gurgles and burrows close to surface.
14.	38º 22' 272" 145º 43' 575"	21 m below road, just past turn cutting	Gurgle and large adult, about 20 cm depth.

Table 2. Number, depth and density of *M. australis* recorded at study sites at Loch Hill. Unknown indicates that a worm was observed but not completely dug out so that its age class could not be determined. ? indicates that weight was not recorded. Immature indicates either juvenile or subadult worm.

Date	Site	Lat long	No of worms	*Age class and weight of known worms	No of egg cocoons	Ave depth of worms (cm) (range)	Area dug m^3	Ave density of worms per m^3
10 Oct 01	1	38º 22' 720" 145º 43' 570"	1	Juvenile (95 g)	0	20	0.8 x0.35x0.2 =0.056	17.9
10 Oct 01	2	38º 22' 722" 145º 43' 563"	5	3 Unknown, 1 subadult, 1 adult	0	55.8 (50-68)	1.20 x1.10x 0.50 (ave depth 0.58) = 0.8	6.5
17 Oct 01	3	38º 22' 725" 145º 43' 567"	3	3 juveniles (18g, 33g, ?)	0	25 (20-35)	1.20x1.50x0.55(ave depth 32.8) =0.47	5.1
17 Oct 01	4	38º 22' 763" 145º 43' 55	2	1 adult (150g), 1 unknown	0	59 (54-64)	1.13x 0.90x 0.90 (ave depth 0.47) .	4.1
13 Nov 01	5	38º 22' 739" 145º 43' 548"	3	1 immature, 1 adult, 1 juvenile (50 g)	1(hatched)	28 (10-50)	110x90x60 (ave depth 0.35)=0.34	8.7
28 Nov 01	6	38º 22' 725" 145º 43' 567"	8-10 (9)	2 Juveniles (30 g, ?), 4 adults (215g, 250g, 220g, ?) and 4 unknowns.	2 (hatched) @ 25 and 15 cm	35 (15-55)	150x150x80 (ave depth 0.45)	8.9
			23			39.3±16.6	Average density of worms	8.5 ± 5.0

Plate 3. Location of study sites 1, 2 and 3 at Loch Hill

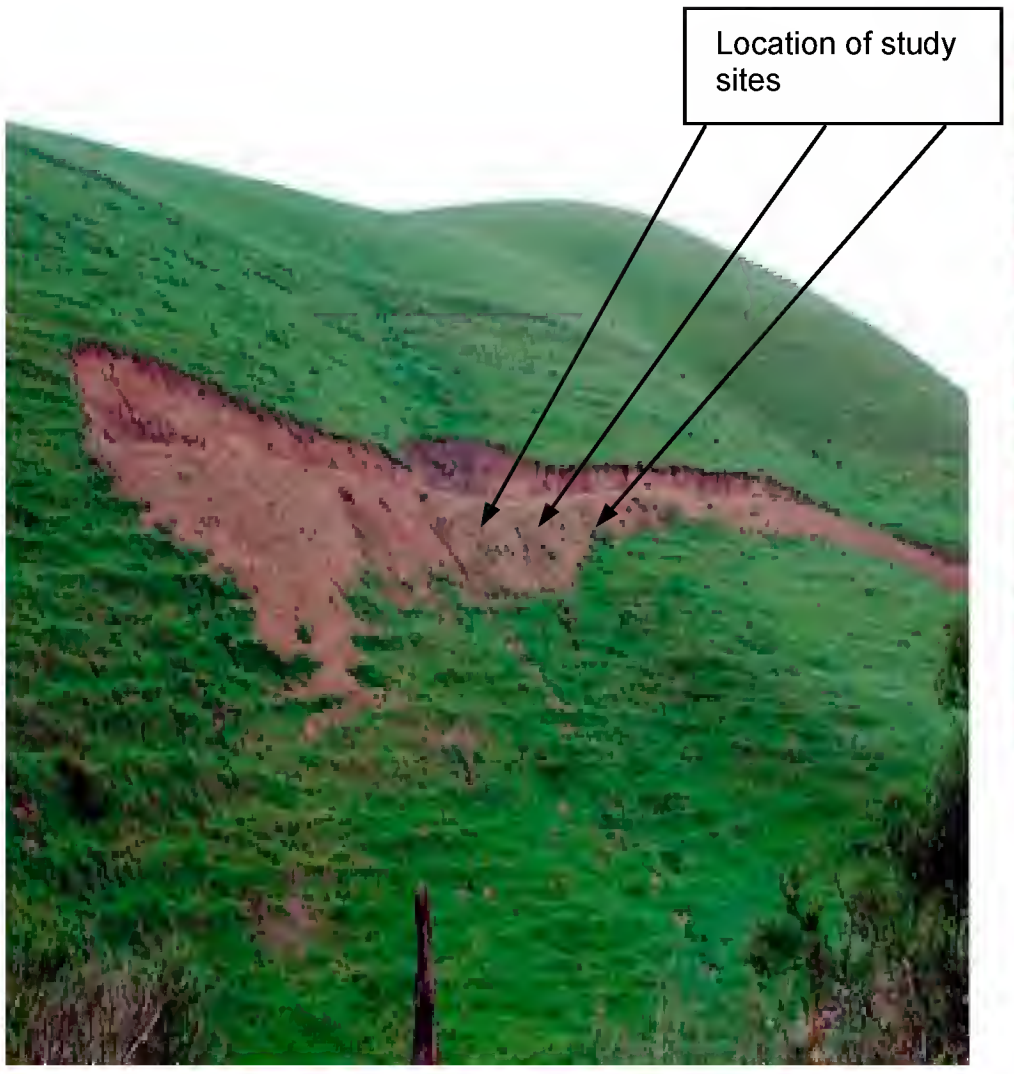

Plate 4. Location of study sites 4, 5 and 6 at Loch Hill

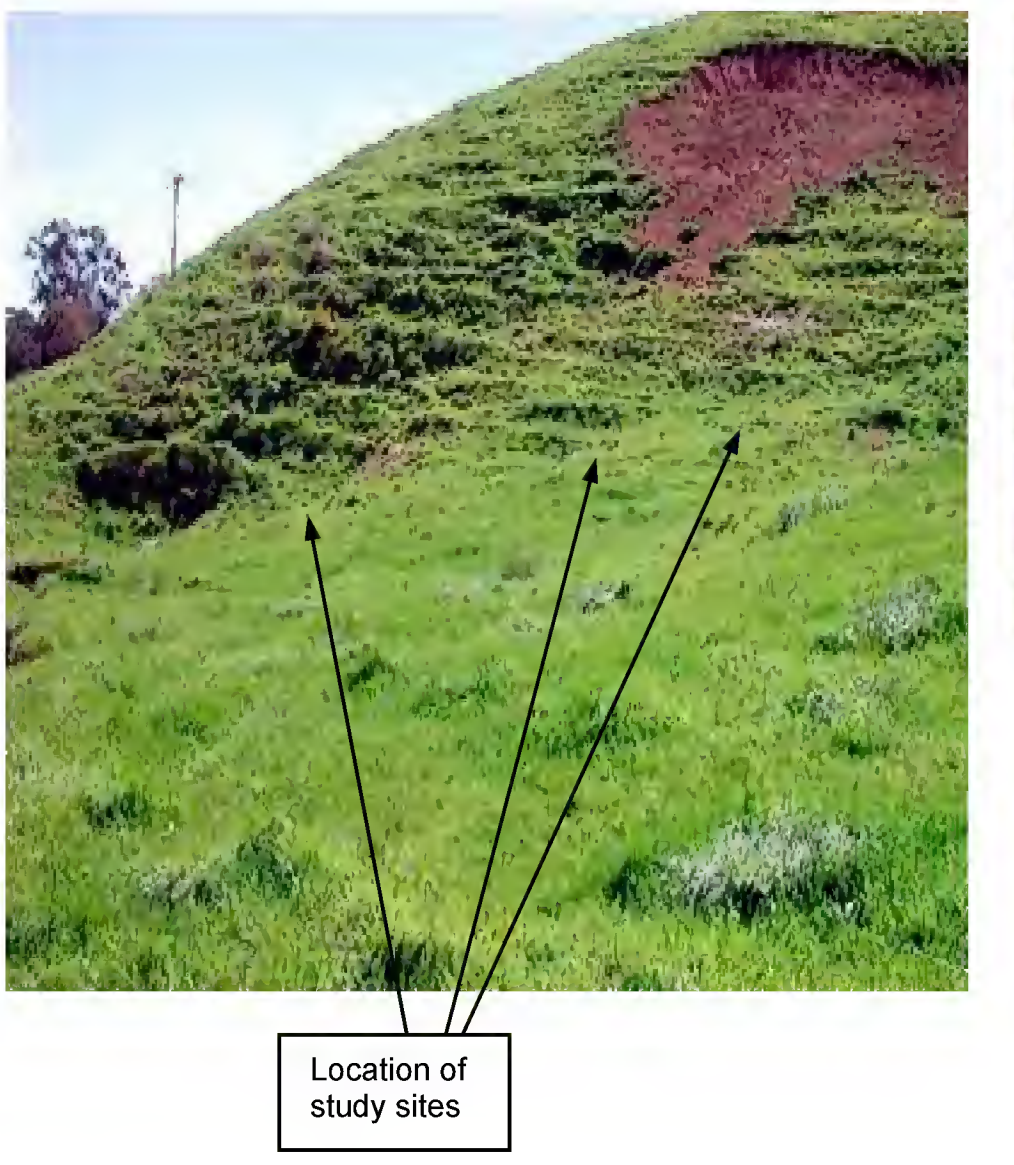

Plate 5. Section of soil showing high density of burrows found at site 6.

Plate 6. Area dug at site 6 where approximately 9 worms were found.

Plate 7a and b. Site 6 showing high numbers of earthworms exposed during excavation

7a

7b

2. SOME PRELIMINARY COMMENTS ON THE SOILS ASSOCIATED WITH THE EARTHWORM POPULATION AT LOCH, VICTORIA

Introduction

This is a preliminary report relating to observations on a population of Giant Gippsland Earthworms near Loch, Victoria. The extent of this population is quite small, being confined to a wedge shaped area extending some 30 m downslope from a cutting into a hill constructed to gain access to a bore test site (Van Praagh and Hinkley, 2001). The widest lateral extent of the earthworm population is found on the lower slopes adjoining a westerly flowing creek running approximately parallel to the road. The earthworms are not found in the valley floor, nor are they found on the adjoining slopes.

Geology

The underlying rocks in the area are Lower Cretaceous sediments of the Strzelecki Group, predominantly sandy silty clay with feldspathic sandstone and mudstone rock fragments (Douglas, 1979).

Soils

The soils throughout Gippsland have been described by Sargeant (1995) at a scale of 1:100 000. Here the soils are mapped as the Strzelecki map unit. At this scale no detail regarding slope and aspect is described for this area. In general the soils of this unit tend to be more clayey and deeper on the southern and south-eastern slopes, and without lime additions they are generally moderately to strongly acidic. In general, decomposing rock is found between 0.8 and 1.5m from the surface.

At this site the track exposure showed that the depth to intact rock was about 0.8 to 1.0 m. A small section immediately to the west of a seepage line appeared to be deeper, and the author gained the impression that some downslope soil creep had occurred.

Geomorphology

The overall landscape consists of maturely dissected, hilly, cleared terrain with relatively youthful valleys. Many of the steeper hillslopes show a regular rippled surface appearance with miniature terraces extending across the slope, usually at right angles to the direction of maximum slope (Plate 1,Van Praagh and Hinkley, 2001). Such ripples, which are often called terracettes, are generally less than 0.5m wide and deep. The appearance of terracettes is often accentuated by the movement of sheep and cattle. Since terracettes may or may not occur on similar topography at similar stocking rates, and may also occur on lightly grazed land, it is usually considered that terracettes are a form of landscape instability and not poor land management.

Carson (1967) related the presence of terracettes to slope, depth of soil, irregularities in the underlying rock mantle and the nature of the vegetation. Where the soil mantle was deeper than a critical depth for the degree of slope, landslips, rather than terracetttes were common.

In his review on slope stability in the Strzelecki Ranges, Brumley (1983) listed the various factors causing slope movement. In summary, these were:

- Steep slopes*
- Deep weathering and residual soil development
- The presence of expansive clay minerals (at this site it is montmorillonite)*
- Seasonal volume changes in plastic clay soils which lower cohesion by developing fissures and assisting water to penetrate the soil profile*
- Progressive release of stored residual and overburden stress during weathering and erosion
- Structural weakness in the Cretaceous rocks*
- Seismicity
- Intense rainfall leading to an increase in soil moisture content and groundwater level*

The factors denoted * are present at this site.

At the site where the earthworms were found, the terracettes were very pronounced and the average slope was between 35 and 40 degrees. No slope measurements were taken elsewhere, but the general impression was gained that the area where earthworms were located had greater micro-relief due to the presence of terracettes than the surrounding area. This is taken to indicate that the land surface is wetter than the surrounding area and may be subject to "soil creep" or accelerated terracette formation. Landscape instability has occurred in this valley in the past, with the author recalling two landslips in the past 20 years on the southern flank of this valley.

Hydrology

The soils where the earthworms were found was quite moist and free water was noted in many of the active burrows. As mentioned earlier, there was a zone of seepage directly above the earthworm population which would have maintained the water content of the soil for extensive periods of time prior to the construction of the cutting. As noted by Van Praagh and Hinkley (2001), water balance within burrows is important for worm movement and respiration. Burrows occupied by the species are very wet and usually have some free-flow of water in them. These water conditions were apparent at this site. During wetter periods of the year, the area appears to be on the point of landscape instability, but no landslides have occurred yet.

3. DISCUSSION - IMPACTS, MITIGATION MEASURES AND FUTURE RESEARCH

Preliminary surveys at Loch Hill reveal the earthworm population to have a relatively restricted distribution, confined to an area of approximately 2500m^2, extending south-east of the tree fern, across the face of the hill to just past the seepage channel. The population extends downslope to just above the tributary of Allsop Creek but is absent from the valley floor. According to the soil investigations, this area corresponds to a section of the hill with very pronounced terracettes, indicating that the land surface is wetter than the surrounding area. The presence of running water down the cut face of the hillslope, generally below the soil surface but exposed during soil excavations, supports this.

Worm density within this area was very high ranging from 4.1 to 17.9 worms per m^3 with an average of 8.5 worms per m^3 calculated. This is a higher density than that recorded nearby for Loch where an average of 2.25 worms per m^3 was found (Van Praagh 1994). However, the Loch study occurred over 3 years and included all seasons. Worms are often not found in January and February, which can bring the average number of worms down considerably. The overall worm density for the site is extremely high and estimated at between 12,500 and 36,250 worms. These figures are based on the hypothesis that the worm is found over the entire 2500 m^2 area. However, it is known that worm distribution is patchy and therefore, further sampling within the worms range would yield zero figures where no worms would be found and this would bring the density estimates down. While these figures are very high and can only be regarded as rough estimates, the high densities encountered at individual sites and the fact that the worms were relatively widespread within the area they occupied, indicates that the area supports very high numbers of earthworms.

Worms were at a slightly more shallow depth at Loch Hill (mean 39.3 cm) compared with that found at Loch where the mean depth was 48 cm.

Population structure data was quite difficult to obtain due to the low sample size and difficulty in obtaining whole (entire) specimens without injury. Four juveniles and one subadult worm were found at study sites 1, 2 and 3. This represents a relatively high number of immature earthworms which is in contrast to other studies that have found that the Giant Gippsland Earthworm populations generally consist predominantly of adult earthworms with a ratio of at least 3 adults to one immature earthworm (Van Praagh 1992, 94). However, it is difficult to determine the significance of this as the sample size is so small and many worms could not be dug out entirely to determine their size class.

Breeding adults are evident by a swollen clitellum that occurs over nine segments between segments xiii to xxi (Van Praagh 1996). No breeding adults were found, which is surprising given that sampling took place within the known breeding season (primarily September –December). Studies have found that adult worms need to be at least 180 g with the average weight of 255 g before breeding can occur (Van Praagh 1996). At least three adult worms found had weights over this threshold (215, 220 and 250g) although only one was close to the average weight of clitellate worms. However, it is thought that adults may not necessarily breed every year and may only do so under favourable conditions. Precisely what those favourable conditions are remains unknown. For example, at Loch, the number of clitellate (breeding) adults varied yearly with only one clitellate adult found in 1988, compared with nine and four in 1989 and 1990 respectively (Van Praagh 1994). The relatively prolonged cool weather in the 2001 spring and summer season may have an effect on the breeding of the species and it would be interesting to note whether breeding is indeed delayed until the warmer weather begins.

Aside from the direct injury to the earthworms during soil excavation for geotechnical investigation, it is difficult to determine the long-term effects, (if any) of the disturbance. The first three quadrats were dug in the area that had approximately 20-30 cm cover of fallen soil over the pasture surface. A relatively high density of active earthworms were found in these quadrats and a high burrow density was noted. As new burrows were evident in the disturbed soil lying over the top of the pasture, the worms appear to have coped with the initial disturbance quite well. The rotting pasture grass, located within the soil profile would provide a food source until new grass established. New grass was already present over the site by late November. The Giant Gippsland Earthworm is a long-lived species and population turnover is slow. Detrimental impacts may not be evident for some time and therefore long term studies are required to measure any changes within the population.

Further field work at the site pre-roadworks to obtain further baseline information on the population is required. A larger sample size would yield more robust data on the densities and population structure of the earthworm at this site.

Impacts

There is no doubt that if road works proceed within the area occupied by worms at Loch Hill, the majority of the earthworm population at the site will be destroyed. The life cycle of the species including long life span, low reproductive and recruitment rates, and low dispersal ability make the fragmented populations, as a whole highly vulnerable to catastrophic events (Van Praagh 1992, McCarthy *et al*. 1994). Mathematical modelling of life characteristics of Giant Gippsland Earthworm populations by McCarthy *et al*. (1994) suggests that removal of even very low numbers of earthworms can significantly impact on the survival of local populations and result in extinction of that population over time.

The impacts of road works at the site on the species are discussed in Van Praagh and Hinkley 2001c. These include directly killing individuals and injury of earthworms during soil excavation, compacting the soil and altering the soil habitat, in particular drainage and moisture regimes at the site. Individuals do not recover if injured and have no capacity to regenerate. Studies at this site indicated worms were found at an average depth of 39.3 cm. Egg cocoons are found within 40 cm of the soil surface with an average depth of around 23 cm (Van Praagh 1994). Thus worms would be particularly vulnerable to direct injury. Depth of excavation for road works will be down to the rock, which would include the entire area occupied by the worms.

Probably the most detrimental impact on the earthworms aside from any direct physical damage to worms during excavation would be the alteration in the soil moisture regimes to the surrounding areas of the site. Soil moisture and

proximity to water are extremely important in governing the distribution of *M. australis* (Van Praagh 1992, 1994). This is particularly evident in the restricted distribution of the species at Loch Hill. The distribution of *M. australis* at Loch Hill is confined to an area of increased soil moisture fed by underground springs (see section on soils of the site). The worm does not occur at other parts of Loch Hill, especially to the east of the hill, as the level of soil moisture is much lower. Any changes in soil hydrology or water table may impact upon those individuals surviving downhill of the road works. Water balance within burrows is important for worm movement and respiration. For example, burrows occupied by the species are very wet and usually have some free-flow of water in them. Compaction caused by heavy machinery affects burrow structure and the worm's ability to make new burrows.

Mitigation Measures

Measures such as conducting the roadworks in summer when the worms are generally deeper in the soil would have little effect in preserving the population as the scale of the work involved is so large and the long-term effects to the site significant eg. Major habitat destruction, damage to individual worms during site excavation, compaction, physical presence of a road, altered drainage patterns and moisture regimes.

The species was found to occupy an area of approximately 2500 m^2. This entire earthworm habitat would be lost during this section of the realignment of the South Gippsland Highway. Therefore, the only mitigation measure available is to attempt to 'rescue' the existing population before and during roadworks and endeavour to protect or restore any earthworm habitat near by that may escape the direct impacts of the roadworks.

Rescuing the earthworm population would involve translocation of some earthworms and egg cocoons to areas of suitable habitat close by and/or attempt to create suitable earthworm habitat in which to release translocated individuals. While the precise habitat parameters for the species are unknown, the most obvious factor of importance is soil moisture. No such work has previously been carried out and the success of such an exercise is unknown. Egg cocoons may present the best chance for the worms' translocation.

The fact the worms appeared to readily burrow into disturbed soil lying over the pasture gives some hope that there may be avenues of translocation of adults worth exploring. The fate of released worms after excavation is unknown. One of the adults recorded was released back down an existing burrow where it soon disappeared. Other earthworms seemed to remain at the mouth of the burrow without attempting to move away. These worms were always covered with soil. However, unless they made new burrows quite quickly or moved into existing burrows, they would be at great risk of desiccation.

Proposed Future Research for Mitigation

While it is unfortunate that a section of the proposed re-alignment of the South Gippsland Highway will most probably result in the destruction of the population of Giant Gippsland Earthworms at Loch Hill, it is thought that the research opportunities resulting from this situation will benefit the long term survival of this species. The benefits that may arise from research on the population at the site may serve as a model to develop conservation guidelines for the species in the future. With the expansion of urbanisation and development of areas within the known range of the Giant Gippsland Earthworm, populations of the earthworm will continue to be threatened by similar disturbances throughout its range.

At present there is little information on the impacts and survival of the species after road works. The proposed research would involve investigation of the impacts of road-works on any individuals that remain at the site, and more importantly, investigate the success of translocation of the species to near by sites. The collection of damaged specimens would also provide important material to examine the genetic variability of the population, which may be important in the translocation of the species.

Research of this kind would be challenging and would indeed need to be innovative and experimental. To be of any value, it would also need to be long term, with at least a five year plan that would include before, during and after monitoring.

Aims of research

- To investigate the impacts of road works on the Giant Gippsland Earthworm
- To investigate the feasibility of translocating either individuals, egg capsules or both from the site to (i) areas close by that do not already support populations of the worm and (ii) to near by sites that already support GGE populations
- To investigate the genetics of the population of worms at Loch Hill
- To examine restoration of habitat for the Giant Gippsland Earthworm including hydrology
- Develop mitigation guidelines for the future conservation of the species

It is very likely that this situation will arise in the future as road works and other forms of soil disturbance continue to occur throughout the South Gippsland region. It is hoped that lessons learnt from the proposed research at Loch will benefit other populations of Giant Gippsland Earthworms that encounter similar forms of disturbance.

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References

Brumbley, J. 1983. Slope instability in the Strzelecki Ranges, Victoria. In *Collected case studies in Engineering geology, hydrogeology and environmental geology*. Eds. Knight, M J, Minty, E J and Smith, R B. Published by the Engineering Geology Specialist Group of the Geological Society of Australia, Inc. Special Publication No 11. Sydney.

Carson, M A 1967. The magnitude of variability in samples of certain geomorphic characteristics drawn from valley side slopes. *Journal of Geology*. 75:93-100.

Douglas, J D 1979. Explanatory notes on the Warragul 1:250 000 geological map. *Geological Survey Report* 57.

Elliot, J.M. 1977. *Some Methods for the Statistical Analysis of Samples of Benthic Invertebrates*. Freshwater Biological Association. Scientific Publication No. 25.

MacCarthy, M.A., Van Praagh, B.D. and Yen, A.L. 1994 *An assessment of Giant Gippsland Earthworm harvesting*. Report to the Department of Conservation and Environment.

Sargeant, I J and others. 1995. *Major Agricultural Soils of South-west Gippsland*. Department of Natural Resources and Environment.

Van Praagh, B. D. 1992. The Ecology, Distribution and Conservation of the Giant Gippsland Earthworm *Megascolides australis* McCoy 1878. *Soil Biology and Biochemistry* 24(12): 1363-1368.

Van Praagh, B.D. 1994. *The biology and Conservation of Megascolides australis McCoy 1878*. Unpublished PhD thesis, La Trobe University.

Van Praagh, B. D. 1996. Reproductive biology of *Megascolides australis* McCoy (Oligochaeta: Megascolecidae). *Australian Journal of Zoology* **43**:489-507.

Van Praagh, B.D. and Hinkley, S.D. 2000a. Survey of the Giant Gippsland Earthworm, *Megascolides australis* in areas to be affected by a realignment of the South Gippsland Highway- East of Loch. Unpublished Report prepared for VicRoads.

Van Praagh, B. D. and Hinkley, S.D. 2000b. Survey of the Giant Gippsland Earthworm, *Megascolides australis* in areas to be affected by a realignment of the South Gippsland Highway- Loch to Bena Stage One. Unpublished Report prepared for VicRoads.

Van Praagh, B. D. and Hinkley, S.D. 2000c. Survey of the Giant Gippsland Earthworm, *Megascolides australis* in areas to be affected by a realignment of the South Gippsland Highway- Loch to Bena Stage Two. Unpublished Report prepared for VicRoads.

Van Praagh, B.D. and Hinkley, S.D. 2001. Survey of the Giant Gippsland Earthworm, *Megascolides australis* around the bottom of Loch Hill in an area potentially affected by a realignment of the South Gippsland Highway. Unpublished Report prepared for VicRoads.